LA-UR -79-585

MASTER MASTER

conf. 781228 2

TITLE: LOW TEMPERATURE FLAT-PLATE COLLECTOR SPACE/WATER HEATING

AUTHOR(S): S. W. Moore

SUBMITTED TO: Presented at the "Reliability of Materials
for Solar Energy Systems Workshop"
December 18-20, 1978

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes.

The Los Alamos Scientific Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545
An Affirmative Action/Equal Opportunity Employer

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Form No. 836 R3
St. No. 2629
12/78

UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

LOW TEMPERATURE FLAT-PLATE COLLECTOR
SPACE/WATER HEATING

Design Presentation

by

S. W. Moore
Los Alamos Scientific Laboratory
P. O. Box 1663, M/S 571
Los Alamos, NM 87545

ABSTRACT

Low temperature flat plate collector designs can take many different forms and make use of a variety of materials. Collectors can be liquid heaters, air heaters, heat-pipe heat exchanged, or a hybrid arrangement when combined with passive systems. They can be factory-manufactured modules, site assembly of factory-manufactured components, factory manufactured into transportable housing, or completely site-constructed. Material selection for all components must be evaluated with respect to operating parameters, performance, durability, and above all, life-cycle costing.

INTRODUCTION

Solar collector design and development is at a point where there is a worldwide effort to study, develop and determine the performance of solar collectors and collector systems. Flat plate solar collector designs range from the more inexpensive plastics and general construction materials to the high thermal performance flat plates and evacuated tube collectors. Much effort, both commercial and government-supported, is being aimed at improving the thermal performance, durability, and reducing costs . All of these results must be carefully evaluated from a "cost of energy delivered to the end use" standpoint.

BASIC FLAT PLATE COLLECTOR DESIGN

Many types of solar collectors have been designed and built. At the low temperatures used for water or space heating, flat plate types work with reasonable efficiency and are relatively easy to construct.

The major functional parts of a collector are the absorber surface, coolant passages, cover glazing and back insulation as shown in Figure 1.

Collectors are designed to maximize absorption of solar radiation and minimize heat losses. The predominant heat loss mechanisms from the front face are by convection and radiation. Convection losses can be controlled by the use of transparent covers or by using convection suppression honeycombs or evacuated collectors. Radiation losses are sometimes reduced by means of a "selective" coating on the absorber surface which has a high absorptance for the solar spectrum and a low emittance for the infrared re-radiation spectrum. Other minor heat loss mechanisms are conduction to the collector backside and edge.

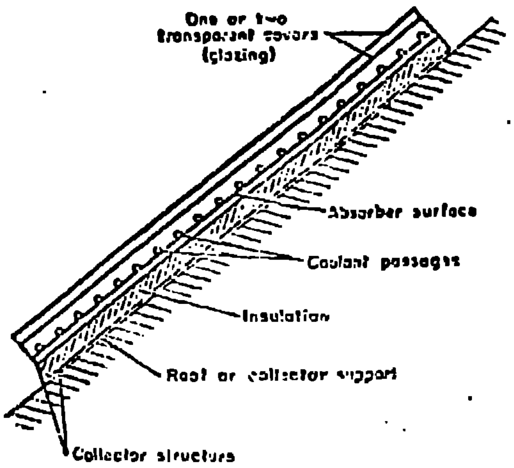

Fig. 1. Basic collector.

Some of the many variations in geometry are shown in Fig. 2. Not shown are the tubular non-concentrating type of collectors.

MAJOR DESIGN CONSIDERATIONS

Absorbers:
- Temperature capability
- Pressure
- Corrosion resistance
- Compatibility w/fluids and absorber coatings
- Fatigue and creep resistance
- Specific heat
- Thermal expansion
- Cost/Durability

*Work performed under the auspices of the U.S. Department of Energy, R&D Branch for Heating and Cooling, Office of the Assistant Secretary for Conservation and Solar Energy.

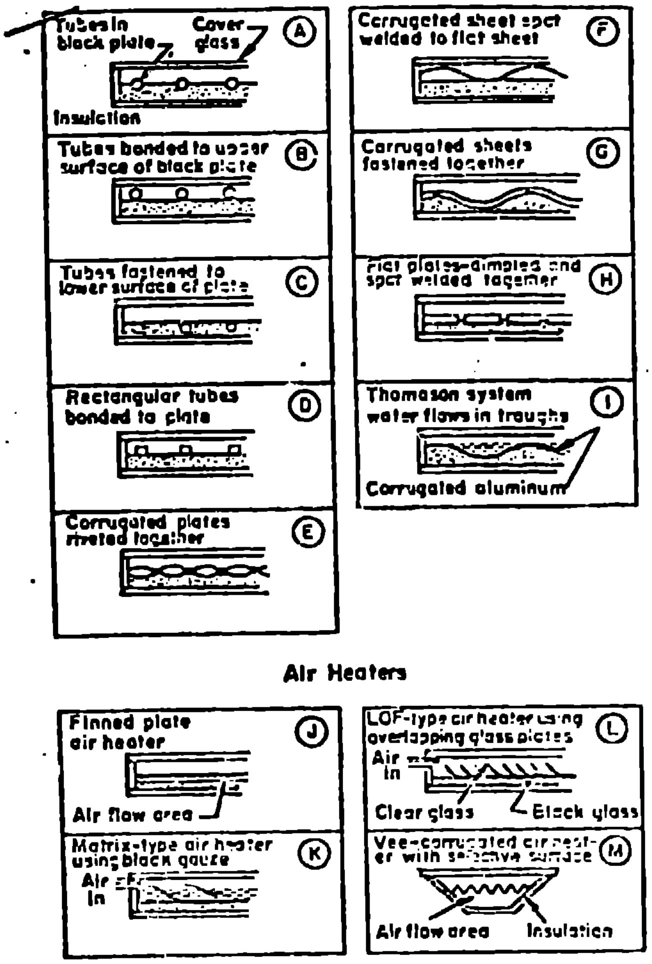

Fig. 2. Flat plate collector types.[1]

Absorber Coatings:
- Optical properties
- Temperature limits
- UV stability
- Moisture resistance
- Cost/Durability

Insulating Materials:
- Thermal Conductivity
- Density
- Temperature limit
- Coefficient of expansion
- Dimensional stability
- Fire and flashpoint
- Flame spread
- Smoke evolution
- Outgassing products
- Cost/Durability

Sealing Materials:
- Temperature limits
- Thermal conductivity
- Flammability
- Compatibility with mating components/fluids
- Elastic properties
- Adhesion thermal stability
- Cost/Durability

Glazing Materials:
- Hemispherical optical transmission
- Temperature capability and resistance to thermal gradients
- UV resistance
- Strength
- Impact properties
- Weight
- Abrasion resistance
- Moisture resistance
- Thermal expansion
- Cost/Durability

Fluids:
- Viscosity
- Temperature limit
- Specific heat
- Flash point
- Boiling point
- Freezing point
- Toxicity, fluid and combustion
- Volumetric expansion
- Density
- Cost/Durability

Examples of basic collector performance and operating limits as functions of varying properties are shown in Figs. 3 through 10 for the following model:[2]

Symbol	Description	Engineering Units	SI Units
QIN	Incident solar flux	300 BTU/hr ft^2	946 W/m^2
TAMB	Ambient temp.	40 °F	4°C
WCP	Flow rate x specific heat of fluid	10 BTU/hr °F ft^2	57 W/m^2 °C
VEL	Wind velocity	2 mph	1 m/s
G	Number of glass panes	2	
K	Extinction coeff. of glass	0.8 in.$^{-1}$	31.5 m
t	Glass thickness	0.125 in./pane	3.2 mm
α	Surface absorptivity	.99	
ε	Surface emissivity	.89	
R_b	Back surface thermal resistance	12 hr ft^2 °F/BTU	2.1 m^2 °C/W

All results are based on the model derived by Hottel & Woertz.[3]

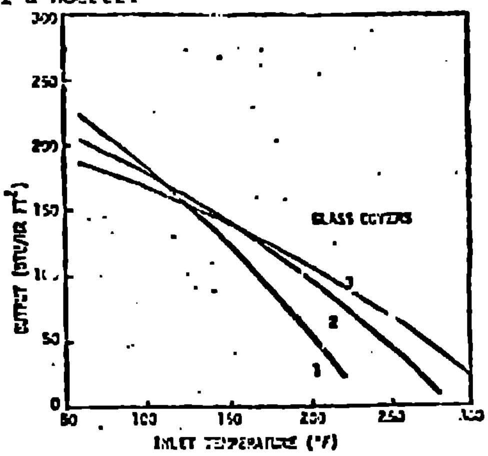

Fig. 3. Effect of number of glass covers.

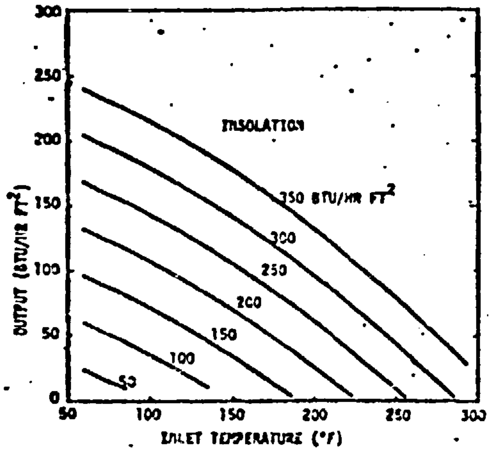

Fig. 4. Effect of insolation.

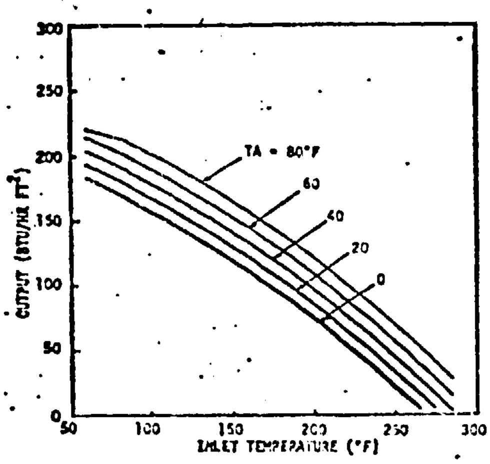

Fig. 5. Effect of ambient temperature.

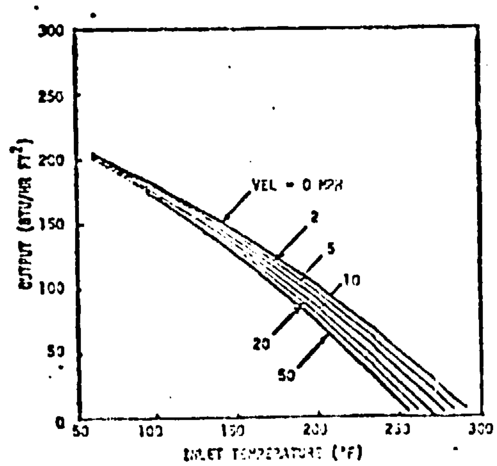

Fig. 6. Effect of wind velocity.

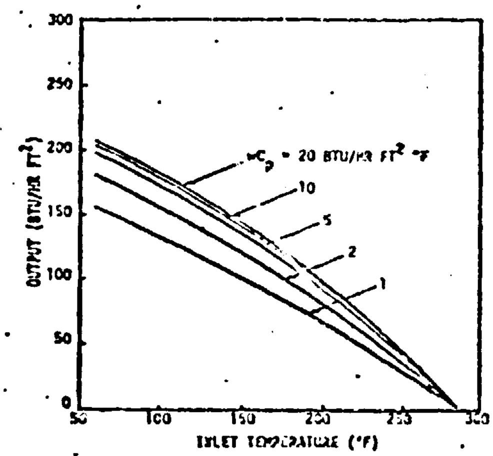

Fig. 7. Effect of collector flow rate.

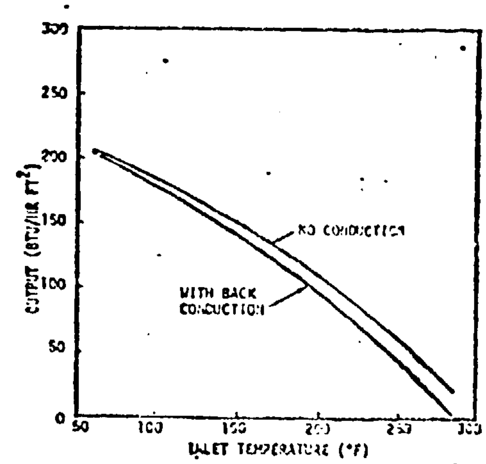

Fig. 8. Effect of back conduction.

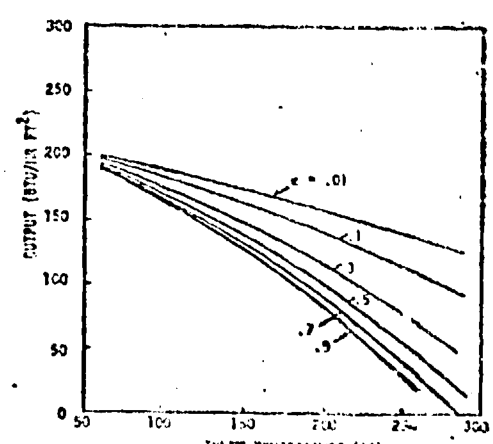

Fig. 9. Effect of emissivity ($\alpha = 0.9$).

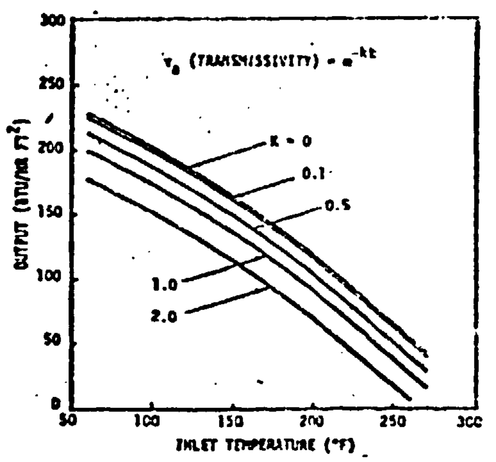

Fig. 10. Effect of glass absorption.

The preceding variations are representative of a specific type of collector and can vary depending upon the actual type and geometry. They do, however, represent the wide range of performances and temperatures dependent upon the basic design and properties selected.

SOLAR ASSESSMENT[4]

In order to assess in detail the state of the technology for solar heating and cooling of buildings, five 2-day meetings were held during December, 1975. Experts were recruited for these meetings from industry both large and small, universities, and government laboratories. The meeting subjects were solar collectors, thermal storage, air conditioning and heat pumps, systems and controls, and non-engineering aspects of solar energy. The meetings based on each topic, discussed the details of the state of the art, the problem areas, and the objectives of necessary research and development.

Solar collectors' needs, materials problems, material capabilities and objectives were established. Results of this assessment were factored into the National Plan for Research and Development in Solar Heating and Cooling[5] and established the framework for the PRDA and RFP solicitations.

DOE COLLECTOR MATERIALS R&D PROGRAMS[6]

There are presently 32 projects funded by DOE specifically focused on evaluating or developing new materials for solar collectors. These projects fall into the following basic six categories:

Development of Selective Surfaces
Cover Plate Study and Development
Coolants and Corrosion
Sealants and Breathing
Freeze Protection
Exposure Testing

These programs, which will be of great assistance in the design of collectors by providing better materials and a greater understanding of solar materials are as follows.

DEVELOPMENT OF SELECTIVE SURFACES

- Berry Solar Products
  "Commercial selective surfaces applicable to copper, aluminum, and stainless steel, their cost effective improvement and evaluation of potential durability in solar absorbers."
- De Soto, Inc.
  "Solar selective absorber coatings by the electrodeposition of paint."
- Honeywell Systems & Research Center
  "Selective paint and black chrome coatings development."
- Lockheed Missiles & Space Company
  "Study of metal/metal oxide and other selective surfaces, coating techniques, stability, optical performance and costs."

COVER PLATES

Honeycomb
- Battelle Pacific Northwest Labs
  "Development of improved cover plates for solar collectors."
- University of California
  "Transparent glass honeycomb for energy loss control."
- Lockheed Missiles and Space Company
  "Optimization of thin film transparent plastic honeycomb covered flat-plate solar collector."

Anti-Reflectance and I.R. Coatings

- General Electric
  "A.R. and I.R. coatings on glass."
- Honeywell, Inc.
  Selective I.R. reflective coatings development", and "Low-cost solar anti-reflection coatings."
- Hughes Aircraft Company
  "Non-glass glazings and surface coatings."
- Research Triangle Institute
  "Non-glass glazings."
- Springborn Laboratories
  "Study of non-glass glazings, surface coatings and UV protective coatings for plastic glazing."
- Tufts University
  "Studies for predictably modifying the optical constants of doped indium oxide films for solar energy applications."

- o University of Wisconsin
  "Polymer surface coatings for down-conversion of UV radiation and inhibition."

Glazing Protection

- o Altas Corporation
  "Development of cost effective techniques and concepts for the protection of glazings against breakage caused by hail, vandals or thermal stresses."

COOLANTS AND CORROSION

- o Battelle Memorial Institute
  "Study corrosion processes of coolants and interaction of fluids, additives and systems."
- o Dow Corning Corporation
  "Development of superior liquid coolants."
- o E I C Corporation
  "Corrosion protection of solar-collector heat exchangers with electro-chemically deposited films."
- o University of Florida
  "Vegetable oils: a superior liquid coolant."
- o Giner Corporation
  "Aluminum corrosion studies for solar heat collectors."
- o Monsanto Research Corporation
  "Study of superior liquid coolants."

INSULATING MATERIALS

- o Dow Corning Corporation
  "Development of improved insulation materials."
- o Solar, INC
  "Development of polyimide materials for use in solar energy systems."
- o Versar
  "Study and survey of thermal insulating materials."

SEALANTS & BREATHING

- o Products Research & Chemical Corporation
  "Development of 400°F resistant sealants for flat plate solar collector construction and installation."
- o Westinghouse Electric Corporation.
  "Study of collector sealants and collector breathing."
- o Ametek, Inc.
  "Development of improved breathing control techniques."

FREEZE PROTECTION

- o Polyset, Inc.
  "Development of a freeze-tolerant solar water heater using cross-linked polyethylene."

EXPOSURE TESTING

- o I I T Research Institute
  "Exposure testing and evaluation of solar collector materials."

One of the major program outgrowths, besides the basic materials development, will be the dissemination of information in the form of User Handbooks.

COLLECTOR PROBLEM AREAS

Many people have begun looking at collector systems which have been operational for some time and have published their findings. Of these, Skoda and Masters[7], DOE (NASA, ASHRAE and UAH)[8] and CASH[9] have provided a good compilation of some of the pitfalls to avoid.

REFERENCES

1. J. E. Yellott, "Solar Energy Utilization for Heating and Cooling," ASHRAE Handbook, 1974.
2. J. D. Balcomb, J. C. Hedstrom, and S. W. Moore, "Research on Integrated Solar Collector Roof Structures," LA-5859-PR, Progress Report, Jan., 1975, Los Alamos Scientific Laboratory.
3. H. Hottel and B. Woertz, Paper No. 64, p. 91, Transactions of the ASME, Feb., 1942.
4. J. D. Balcomb and J. E. Perry, "Assessment of Solar Heating and Cooling Technology," LA-6379-MS, Informal Report, Los Alamos Scientific Laboratory.
5. "National Program Plan for Research and Development in Solar Heating and Cooling for Buildings, Agricultural and Industrial Applications," DOE/CS-0008, U.S. Department of Energy, August, 1978.
6. S. W. Moore, "Collector Materials R&D Overview, 3rd Annual Solar Heating and Cooling R&D Contractors Meeting, Los Alamos Scientific Laboratory, September, 1978.
7. L. F. Skoda and L. W. Masters, "Solar Energy Systems - Survey of Materials Performance," NBSIR 77-1314, October, 1977.
8. Mitchell Cash, "Hardware Problems Encountered in Solar Heating and Cooling Systems," DOE/NASA TM-78172, May, 1978.
9. "Solar Heating and Cooling Project Experiences Handbook," PRELIMINARY ISSUE, Sponsored by DOE, July, 1978.